Do You Have to See Everything – All the Time? Or is it at All Possible?

Handling Complex Graphics Using Multiple Levels of Detail Examples from Geographical Applications

Dr. ing. Rune Aasgaard
SINTEF Applied Mathematics
PO Box 124 Blindern
N-0314 Oslo
NORWAY

ABSTRACT

This presentation motivates the use of View Dependent Level-of-detail (LOD) in complex graphical displays, both for reducing computer workload and improving visual quality. In addition, some challenges are discussed.

When generating perspective views of geographical data the resulting image can be seen as a map with a very flexible "scale". Areas near the viewer require a high data density, while areas in the background can be shown with very simplified graphics. Using data with only one single detail level gives the view some "myopia" and restricts the possibilities for giving overview presentations. LOD methods on the other hand support several "scales" in the same data model.

LOD MODELS

In general a LOD model is based on storing the model as a coarse base model and a set of refinement operations. The refinement operations transform the model from a coarser to a more detailed state. Each refinement may be dependent on the model being in a given state, that some of the other refinements are applied before. This introduces dependencies between the refinement operations.

The base model with the refinement operations gives a set of possible refined models. If each refinement operation is dependent on only one direct precedent (and all ancestors, by transitive closure) the set of refined models are organized in a strict hierarchy, a tree. If, on the other hand, the refinement operations can be directly dependent on more than one previous refinement the set is organized into a directed acyclic graph.

The refinement operations are reversible, so that a given valid refined model can be simplified to a less detailed model by applying the reverse refinement operations. The complete LOD model (base model and refinement operations) is usually constructed in a "bottom-up" fashion starting with a detailed model, and finding a refinement operation that generates the detailed model from a less detailed model. The less detailed model is again used in a new iteration finding a refinement operation and an even less detailed model.

Associated with the model is a quality measure quantifying the benefit of applying a refinement operation. During construction of the LOD model this is computed and stored together with the refinement operation.

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **00 APR 2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Do You Have to See Everything All the Time? Or is it at All Possible?**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **SINTEF Applied Mathematics PO Box 124 Blindern N-0314 Oslo NORWAY**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001665, RTO-MP-105 Massive Military Data Fusion and Visualization: Users Talk with Developers., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**26**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The quality measure is also used to guide the construction process, for finding the reverse refinement operations that gives least reduction in quality. In a view-dependent LOD system the quality measures are transformed into the screen space, and are compared with the resolution of the viewing system for evaluating the adjoining refinement operation.

LOD models have a higher level of complexity than traditional single level of detail models, but they also have some built-in advantages:

- Hierarchical search system – the hierarchy of refinements can be used for searching.
- Clustering of data – data about physically near objects have a large probability of being in the same branch of the refinement hierarchy.
- Compression – in many cases the refinement operations only need to store information about local changes, which might compress better than full resolution data.

GEOGRAPHICAL DATA

The challenges are illustrated with examples for some important geographical data types.

Preparing data for LOD viewing has some resemblance to traditional cartographic generalization, but there are several problems that have to be addressed:

- Speed – the models must support interactive tours.
- Range of scales – from street to global view.
- Continuity of model – no visible break between detail levels.
- Data volume – data may be transferred over a network.
- Incremental loading – avoid retransmitting data.
- Heterogeneity – different data types are handled with very different methods. Some of the data integration may be postponed until the final visualization process.

Terrain Elevation Model

There has been developed several methods for LOD surface models. Surface models have a strong continuity, and the refinement operators have a dense network of dependencies to neighboring areas. Several of the LOD surface models can be used for large terrain models.

Terrain Texture Coverages

In its simplest form this can be implemented by an image quad tree. Each detail layer is handled by a new set of images, with doubled resolution for each successive layer. In a more advanced version the image pyramid can be implemented by using a wavelet hierarchy that would only store local refinement operations. Several methods exist, both open standards and proprietary solutions, like JPEG2000, MrSID and ECW.

Discrete Objects

LOD models for discrete objects are well known in current graphic libraries. The traditional LOD approach has been to store separate models for each detail level. To conserve storage space and network capacity it would have been advantageous to use compact update operations instead. Currently there is a large research effort on automated methods for establishing simplification and aggregation hierarchies for buildings and other man-made objects.

Transport Networks

There is currently no widely adapted method for handling transport networks in LOD structures. Using classification hierarchies (Main road – regional road – local road) gives some simple way of structuring roads, but it gives no guarantee of maintaining network continuity or avoidance of cartographic conflicts. There are still many challenges for future research.

FINALLY…

To answer the initial question: No, we can't see everything, all the time. Neither do we want to! However, we can use LOD models for developing a system where we can move fast between a global and a local view. Several suitable methods are known and described in the literature, but for some very common data types more research is needed.

Do we have to see everything - all the time?

…or is it at all possible?

Dr. ing. Rune Aasgaard

What do we want?

- Visualization of large data volumes
  - Virtual world
- Navigation in virtual world
  - Fly
  - Walk
- Several scales
  - Global view
  - Detail view
  - Perspective view

With one level of detail?

- Resolution and detail level determined by
  - the “best” possible resolution
  - huge amounts of data!
- How far can you see
  - before the finest detail levels are irrelevant?
  - before your computer is exhausted?
- Usual solution
  - cut
  - fog
  - “shortsightedness”!
- Simple data structures

With few levels of detail?

- A “fine” level of detail + overview
  - the fine data level - as before
  - less detailed levels
- Like a series of map scales
  - 1:5000
  - 1:50000
  - 1:250000
- Visible jump
- Poor flexibility
- Relations between levels?
  - a data management challenge!

With continuous level of detail?

- Smooth transition from detail view to global view
- Data structure:
  - coarse base model
  - local refinement operators
    - quantify benefit of refinement
    - reversible refinement
  - adjacency information gives dependencies
- Top-down traversal
  - Usually bottom-up creation
- More complex data structures, but:
  - spatial storage clustering included
  - spatial search system included

Continuous?

- "Continuity" in detail level
  - Smooth transition from coarse to fine
  - No "popping"
- "Continuity" over geographical domain
  - Smooth transition from foreground to background
  - No cracks
- Infinite number of detail levels?
- Geomorphing?

Common geographical data types

- Terrain surface
  - Global, continous
- Area coverages
  - Images, land classifications
- Networks
  - Roads, rivers, railroads
- Point features
  - Buildings

Combined models

- Unified surface models
  - Different features need different methods
    - Terrain - mainly smooth
    - Buildings - “boxy”
    - Terrain features - sharp
  - Elevation as function of position may be broken
- Surface with added features
  - Features connected to surface
  - Features in surface
- Surface with projected images
  - Trivial

Surfaces

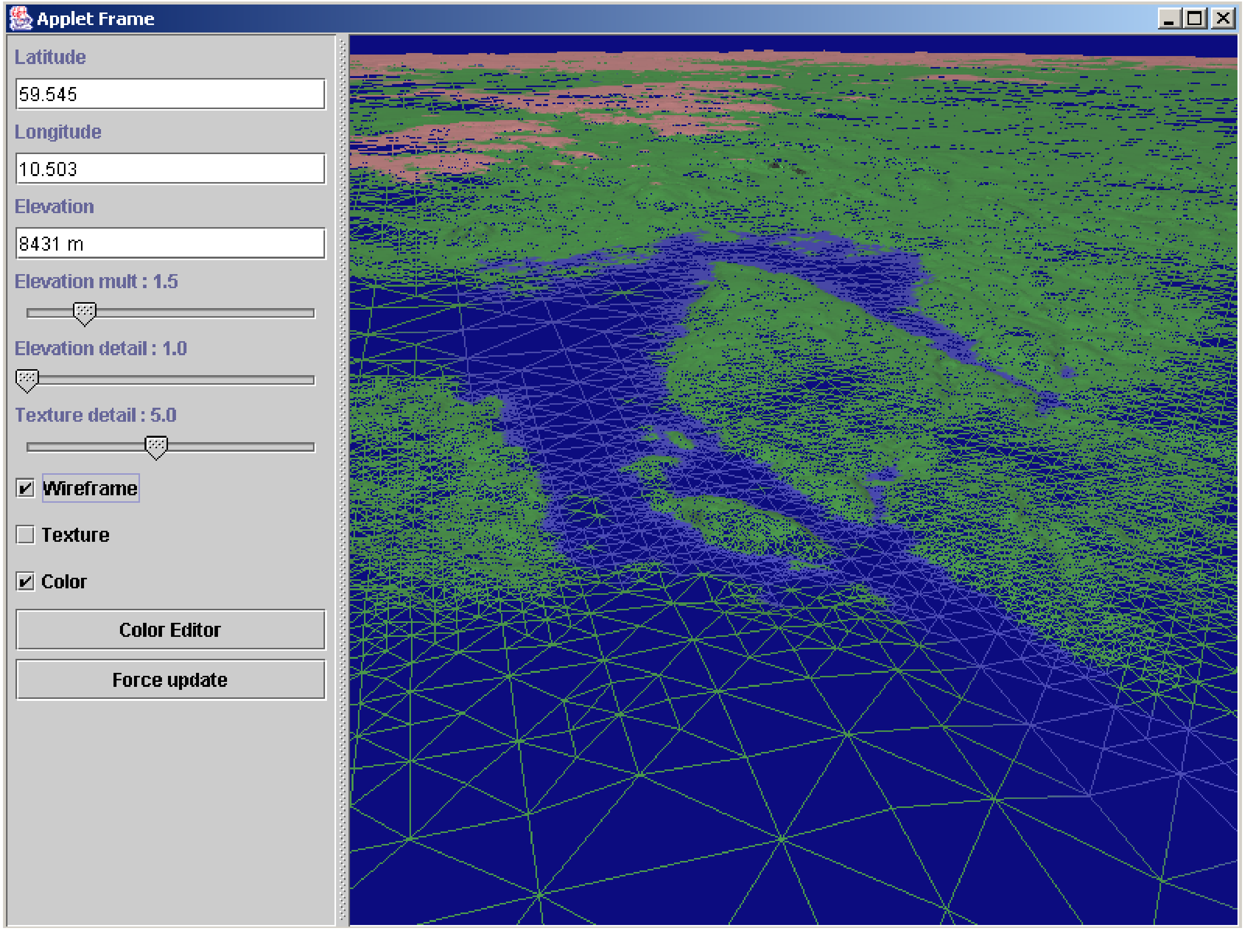
- Terrain surfaces
  - Above water
  - Seafloor
  - Sharp edges?
  - Terrain features?
    - Man made?
    - Natural?
- Surface simplification?
  - Smooth surface?
  - Feature dependent?

Surfaces

- Triangulated models
  - Regular triangulations
    - Vertices at fixed positions
    - Simpler data structures
  - Irregular triangulations
    - Free vertex placement
    - Can handle feature points and lines in surface
- Smooth models
  - Multi level splines
  - Wavelets

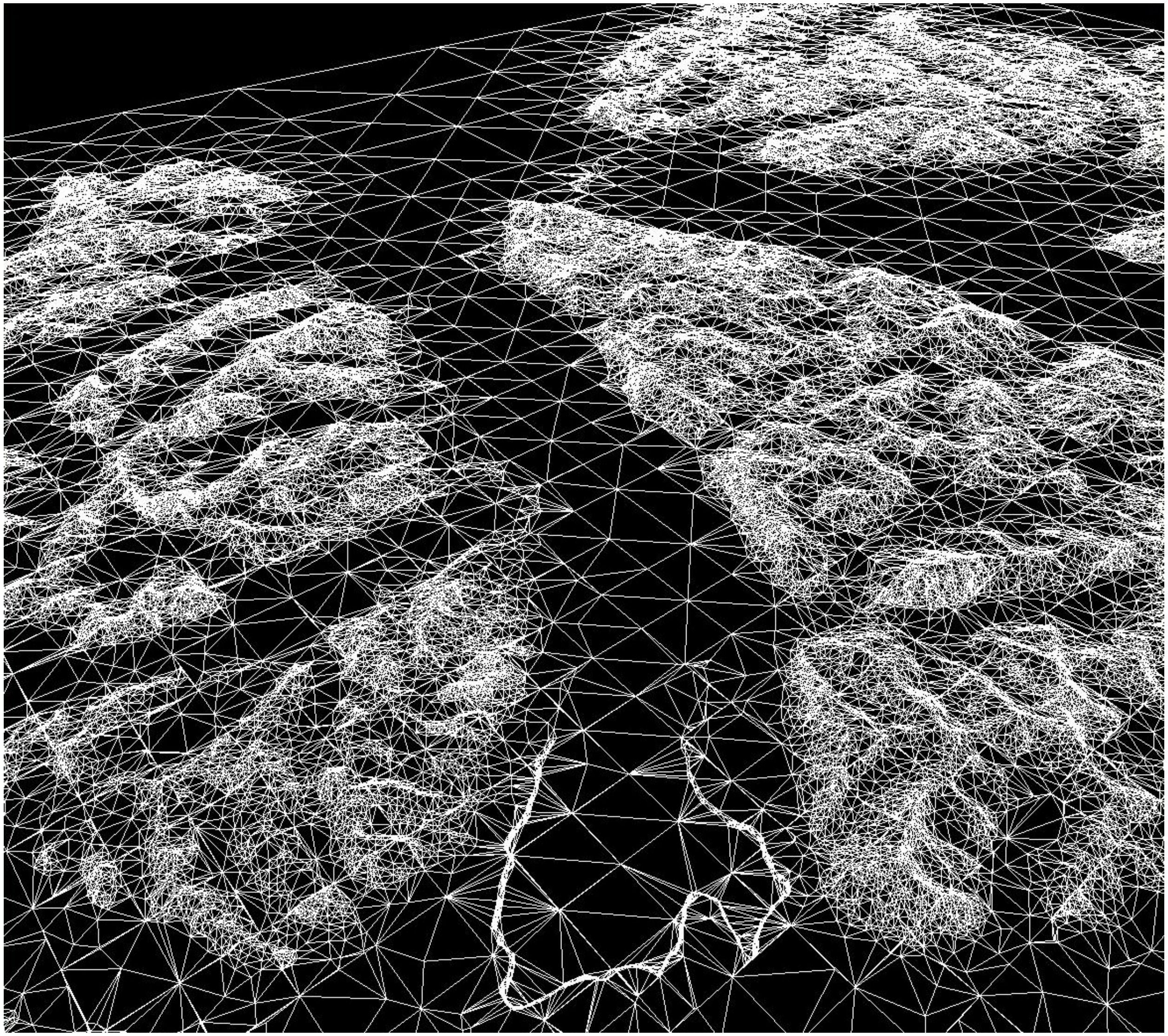
Surfaces

Hierarchical regular triangulation

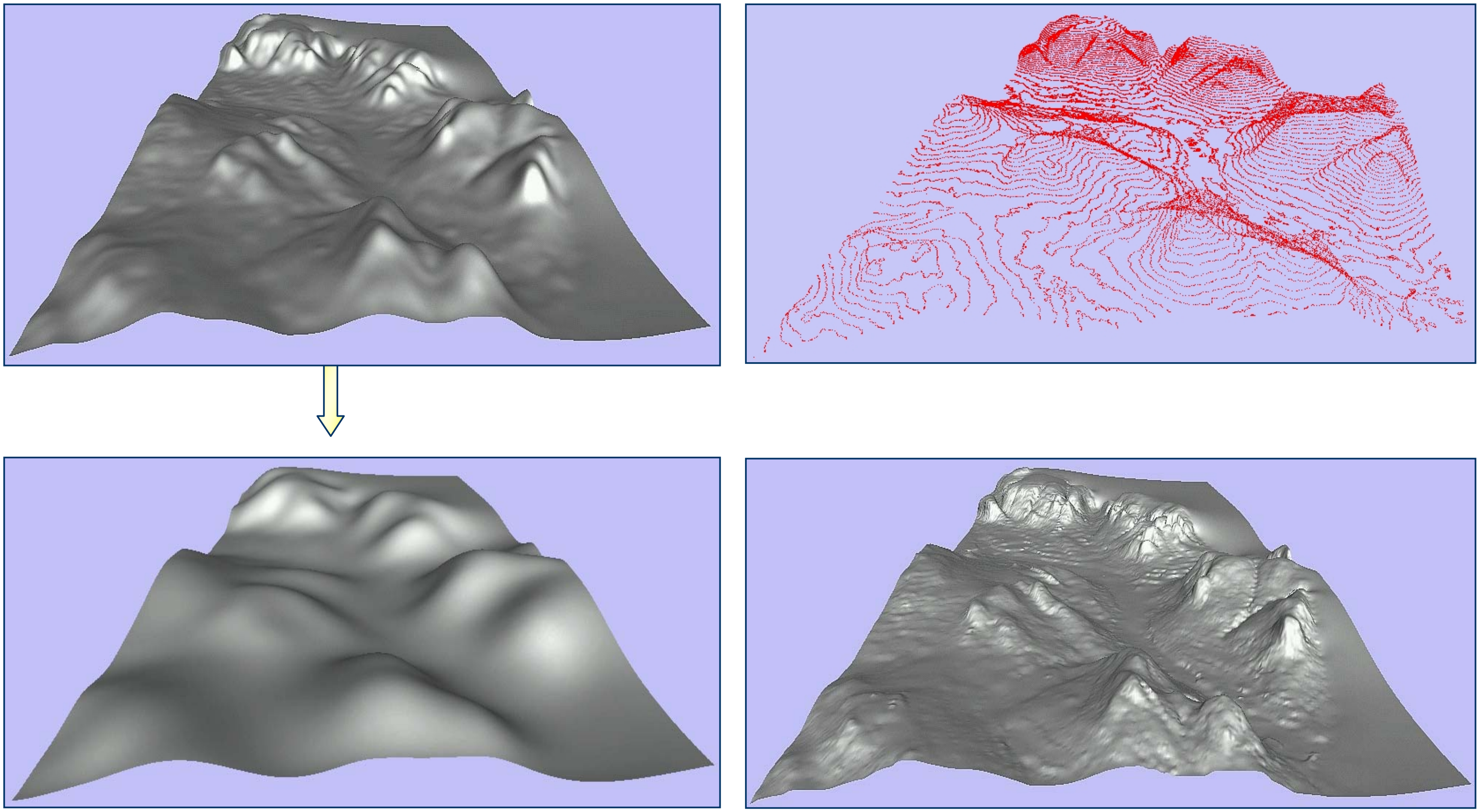


Surfaces

Hierarchical irregular triangulation



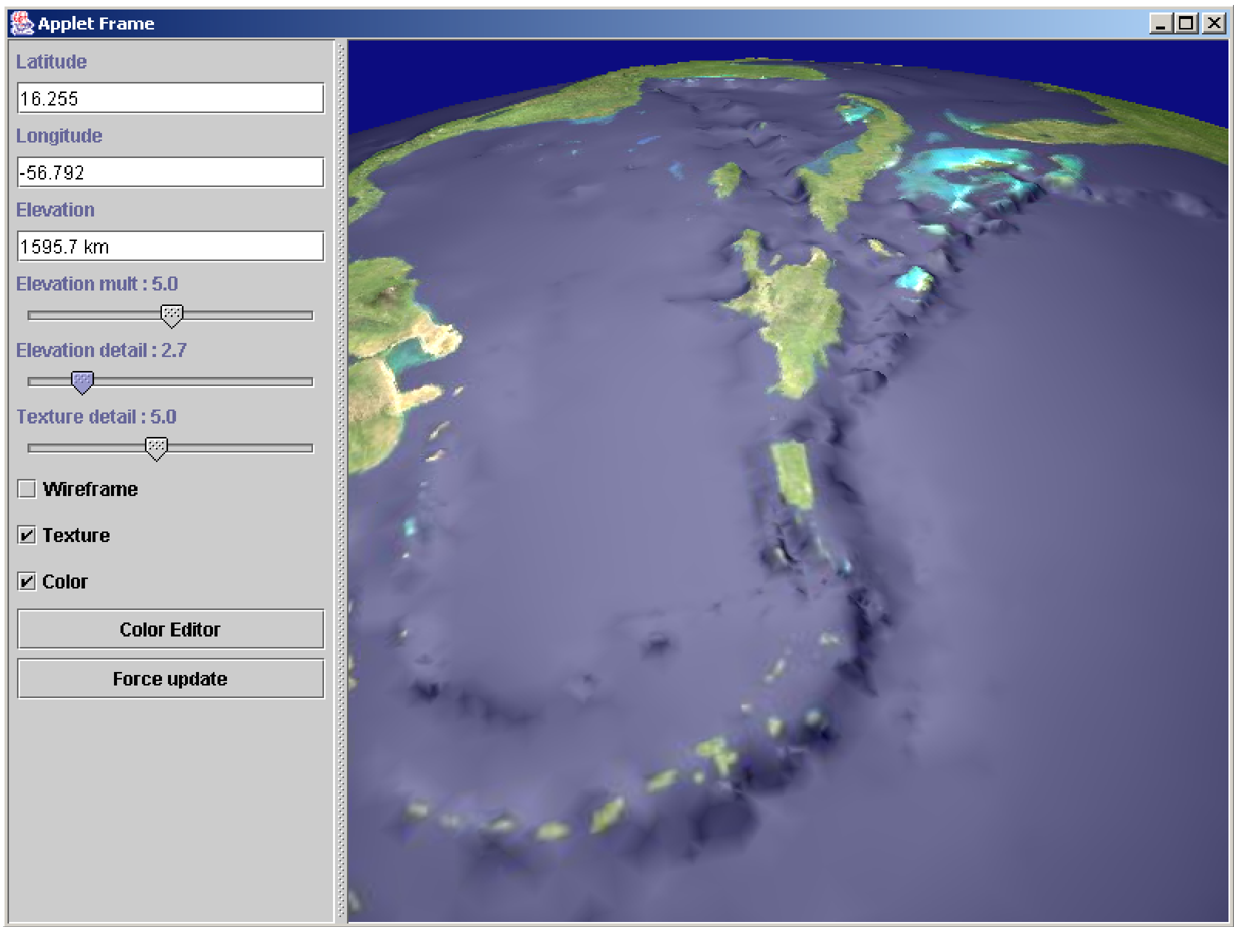
Multi level splines



Area coverages

- Texture image pyramids
  - Set of images
  - Wavelet coefficients
- Natural or natural-looking images
  - Smooth or chaotic borders
  - Noisy areas
- Symbolic images
  - Sharp borders
  - Unicolored areas
  - Regular patterns

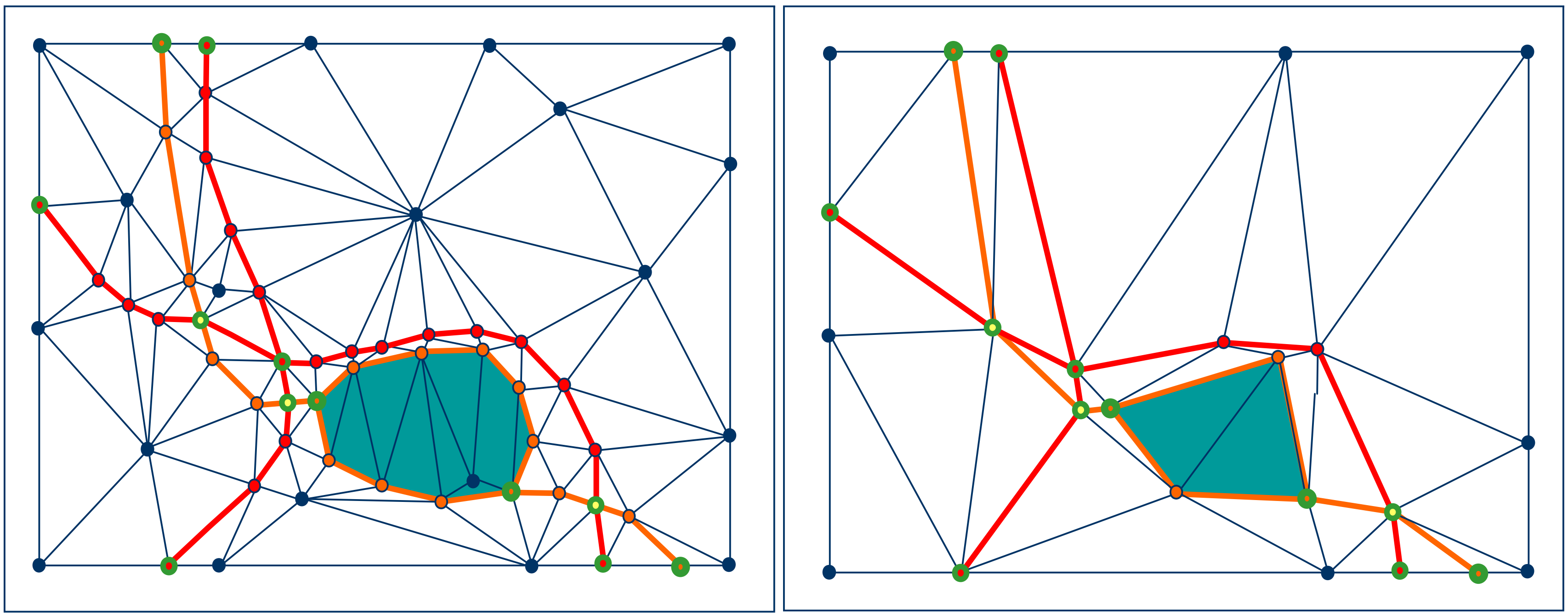
Terrain and Textures



Networks

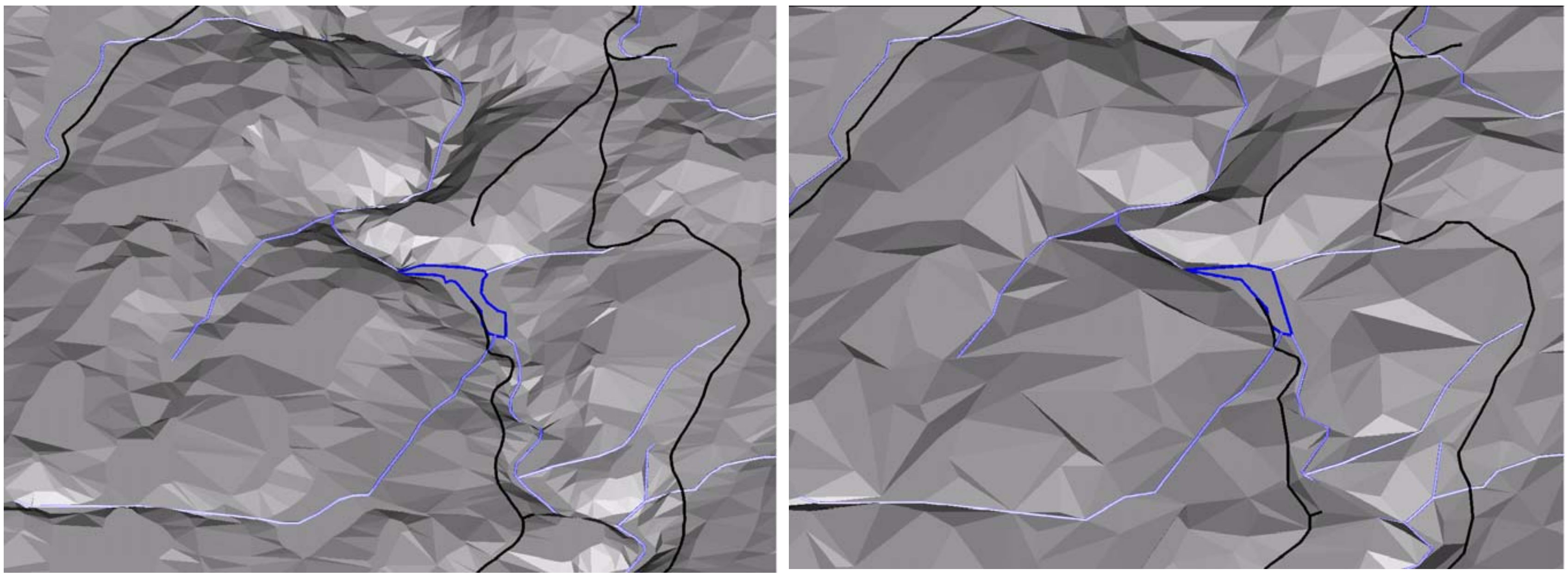
- Transport systems
  - Roads
  - Rivers
  - Railroads
- Some generalization algorithms exist
- Adjacency information necessary!
  - The connectivity of the network must be maintained
  - Links may be removed only if alternative routes exists
  - Dependency on terrain and buildings
- Continuous level of detail?

Terrain and Network



Terrain and Network

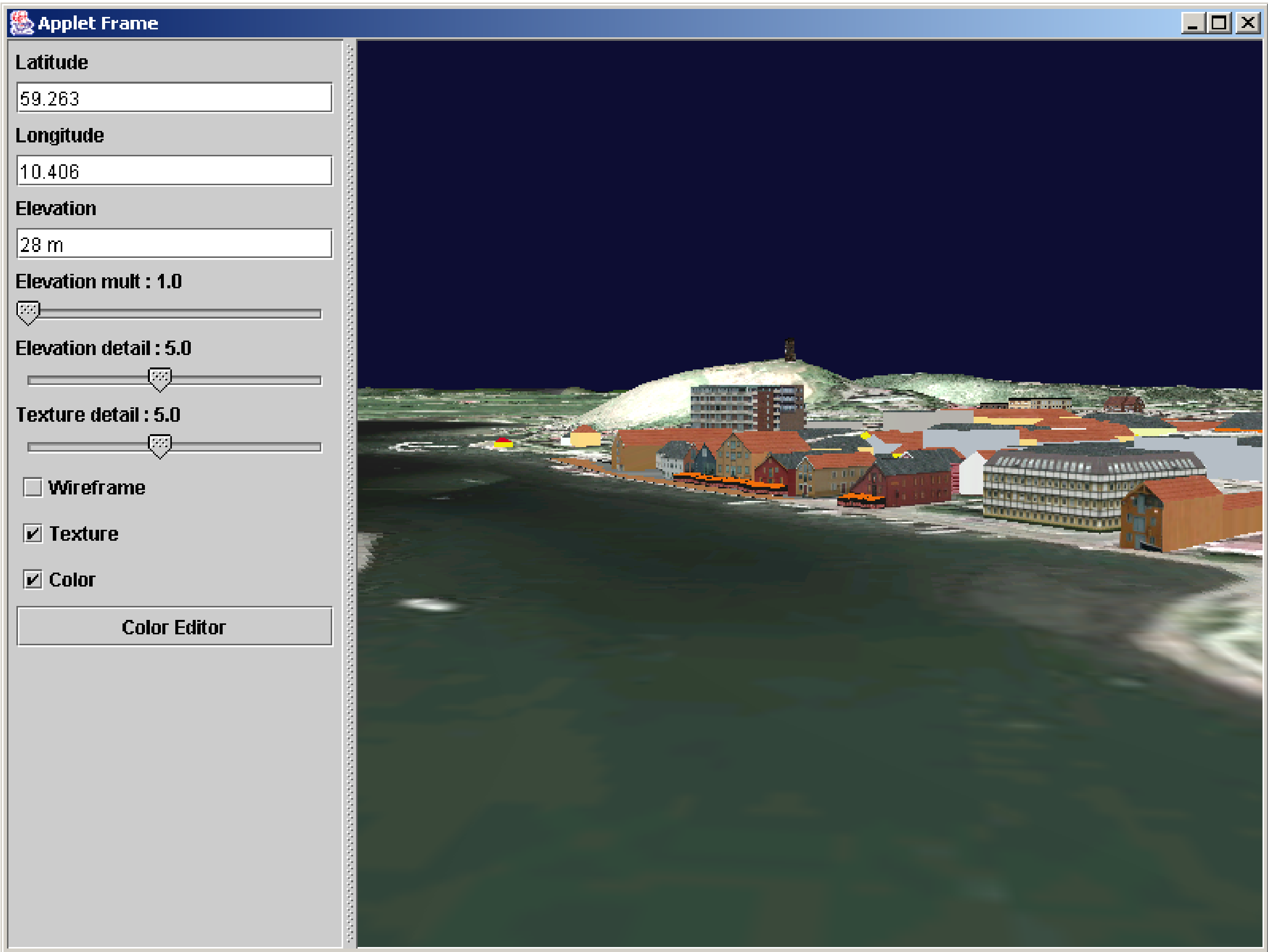
Terrain and Network



Buildings and other point objects

- Simplification and Aggregation hierarchies
  - Building - consists of sub parts
  - Buildings - group into blocks
  - Maintain “boxy” appearance!
- Limited adjacency information
  - Simple clustering
- Current research on handling of building models
  - Data extraction from images
  - Data extraction from laser scanning
  - Automated generalization
  - Hierarchical models

Terrain, Textures and Features



Can we see everything, all the time? No!

However, with a decent hierarchical data model we can:

- Move between global and detail view
  - …large scale changes
  - …fast!
- Suppress less important features
- Emphasis important features, even at a distance

…and see what really matters!